INTEROFFICE MEMORANDUM

TO: JOHN HOGAN

FROM: KEN HORSFALL

SUBJECT: COOLING TOWER SIZING CODE

DATE: FEBRUARY 16, 2004

CC:

John,

In the code review meeting last week, it was suggested that we delete the requirement for the minimum cooling tower sizing. This requirement is summarized as follows:

- Condenser water flow rate shall be ≥ 2.5 GPM/Ton.

- The return water temperature to the tower shall be ≤ 86°F based on 66°F ambient wet bulb temperature.

These restraints have created the condition where the condenser water loops in most new buildings are now designed for 76/86°F water.

It was suggested that engineers should be given the freedom to select the appropriate condenser water flows and temperatures based on the nature of the system and architectural constraints of the building. This may be suitable for some engineers with the knowledge and available design time required to properly design this loop. However, in my experience, a majority of the engineers skip this step.

Consider the condenser system designs installed prior to this code going into effect - most were at some nominal value of 85/95 or 80/95 or even 85/100 with little regard to the system performance. If we strike this code, I suspect that we'll just go back to the way it was done before – with some of the more astute engineers getting it done right and the others just getting it done.

What I would prefer is to add a statement that would keep the sizing requirements the same but give the designer an "out" if the architectural constraints or cost impact to the project is prohibitive. I'd also like to see us adopt CTI certification as a requirement for all cooling towers. I find it interesting that all products, from 2-ton package units and up, have a rating standard which is referenced as part of the code. Yet cooling towers do not. In the most recent edition of California's Title 24, they have included CTI certification

for all cooling towers installed in California. I'd like to see Seattle adopt similar verbiage as that given in footnote "b" of Table 112-G from the latest Title 24 document (attached).

Cooling Tower Sizing Example

In considering energy efficiency in a chilled water cooling plant, one of the best ways to save energy is to reduce the power requirement of the water chiller. Although pumps and tower fans have an impact on the overall energy use, it is usually a small portion of the total power input at plant loads above 30% (see attached chart).

The best method to reduce chiller power input is to reduce the lift, i.e. the pressure differential across which the compressor must operate. One method used to reduce lift is chilled water reset, but this can have negative impacts on other parts of the system, including increased chilled water and air handling unit fan energy. The second (and more direct method) is to reduce the condenser temperature. The best way to do this is by providing adequate surface area for the condenser water heat transfer to take place.

The measure of cooling tower efficiency is the approach temperature, i.e. the difference between the ambient wet bulb temperature and the water temperature leaving the tower. The attached chart shows the approach temperature of three different tower designs as a function of ambient wet bulb temperature. It is clear from this chart that a tower designed for better efficiency (small approach) at full load maintains the ability to outperform the other towers at lower ambient temperatures.

In this study, I selected a 500-ton variable speed chiller and a matched cooling tower at three distinct design points:

a) 76°F ECWT with 3 GPM per ton in the condenser (nominal 76/86 design)

b) 83°F ECWT with 3 GPM per ton in the condenser (nominal 83/93 design)

c) 80°F ECWT with 2 GPM per ton in the condenser (nominal 80/95 design)

Based on typical operating schedules, the results were as indicated in the following table:

% Load	Approach Temperature			System kW		
	76/86	83/93	80/95	76/86	83/93	80/95
100%	10.60	17.00	14.00	333	359	354
95%	9.82	16.62	13.15	293	326	313
90%	9.60	16.27	12.96	265	296	283
85%	9.12	15.86	12.73	239	269	257
80%	8.85	15.41	12.46	217	245	233
75%	8.55	14.91	12.16	197	224	213
70%	8.22	14.35	11.81	177	205	190
65%	7.84	13.74	11.41	161	187	176
60%	7.43	13.05	10.96	148	170	160
55%	6.98	12.30	10.46	135	154	144
50%	6.48	11.48	9.90	124	139	129
45%	5.94	10.56	9.16	114	126	117
40%	5.35	9.53	8.47	105	114	106
35%	4.72	8.43	7.71	96	104	95
30%	4.14	7.25	6.87	95	94	85

The system kW includes the chiller, pumps and tower fan[1]. The tower fan speed is kept constant and represents a worse-case scenario for fan kW as a portion of the total. I've run several scenarios and the bottom line is that the more surface area you have in the tower and the lower condenser water temperature you generate, the lower the system cooling cost will be.

The only exception might be on a job with a lot of hours below 35% load where the condenser water pump head is high. This was the case in a job we did a few years ago at Fisher Plaza where we arrived at a 78/97 as the most appropriate design - so it does happen, but it's rare. In the Fisher Plaza case, we had a raised floor design with a 60+°F air temperature and lot of economizer hours with very low chiller hours, most of which were at loads below 35%. But this is the only case in the last 8 years that I can think of that this condenser design made any sense.

In conclusion, I think we should leave the current cooling tower design code as is, with the possible addition of a statement to allow alternate sizing if architectural constraints or system costs are prohibitive. In addition, CTI certified performance for all cooling towers should be adopted by this code.

Thank You,

Ken Horsfall

Ken Horsfall
Washington Air Reps, Inc.

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[1] Chilled water flow = 2.4 GPM per ton at 60 Ft for all cases. Condenser water flow = 3.0 GPM per ton at 40 ft. for the 76/86 and 83/93 cases. Condenser water flow = 2.0 GPM per ton at 25 ft for the 80/95 case. Tower fan BHP = 23.0 for the 76/86 case and 18.0 for the other cases.

TABLE 112-G PERFORMANCE REQUIREMENTS FOR HEAT REJECTION EQUIPMENT

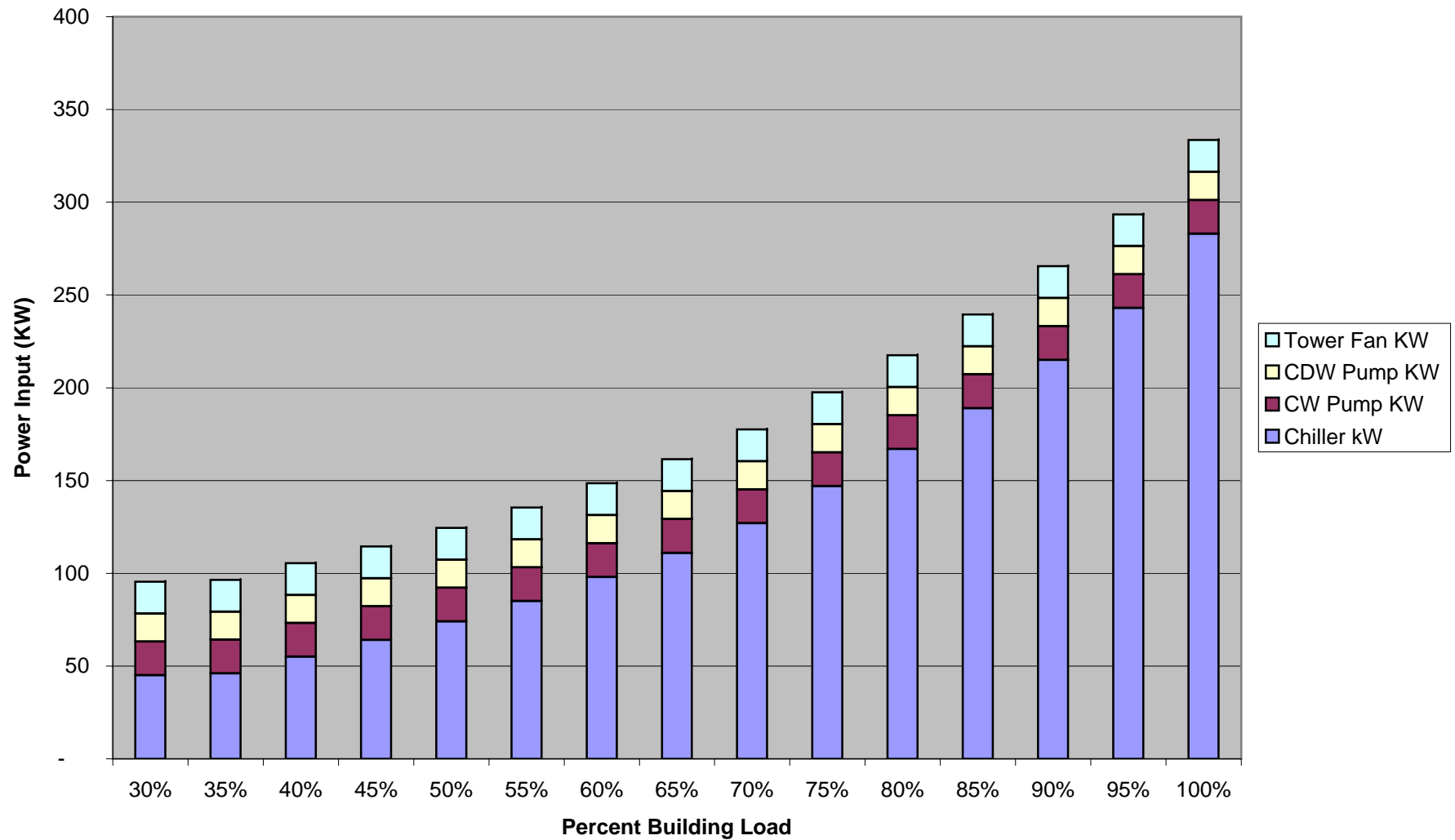| Equipment Type	Total System Heat Rejection Capacity at Rated Conditions	Subcategory or Rating Condition	Performance Required [a,b]	Test Procedure [c]
Propeller or Axial Fan Cooling Towers	All	95°F Entering Water 85°F Leaving Water 75 °F wb Outdoor Air	> 38.2 gpm/hp	CTI ATC-105 and CTI STD-201
Centrifugal Fan Cooling Towers	All	95°F Entering Water 85°F Leaving Water 75 °F wb Outdoor Air	> 20.0 gpm/hp	CTI ATC-105 and CTI STD-201
Air Cooled Condensers	All	125°F Condensing Temperature R22 Test Fluid 190°F Entering Gas Temperature 15°F Subcooling 95°F Entering Drybulb	> 176,000 Btu/h·hp	ARI 460

[a] For purposes of this table, cooling tower performance is defined as the maximum flow rating of the tower divided by the fan nameplate rated motor power.

[b] For purposes of this table air-cooled condenser performance is defined as the heat rejected from the refrigerant divided by the fan nameplate rated motor power. [c] Cooling towers shall be tested using the test procedures in CTI ATC-105. Performance of factory assembled cooling towers shall be either certified as base models as specified in CTI STD-201 or verified by testing in the field by a CTI approved testing agency. Factory assembled cooling towers with custom options added to a CTI certified base model for the purpose of safe maintenance or to reduce environmental or noise impact shall be rated at 90% of the CTI certified performance of the associated base model or at the manufacturer's stated performance, whichever is less. Base models of factory assembled cooling towers are cooling towers configured in exact accordance with the Data of Record submitted to CTI as specified by CTI STD-201. There are no certification requirements for field erected cooling towers.
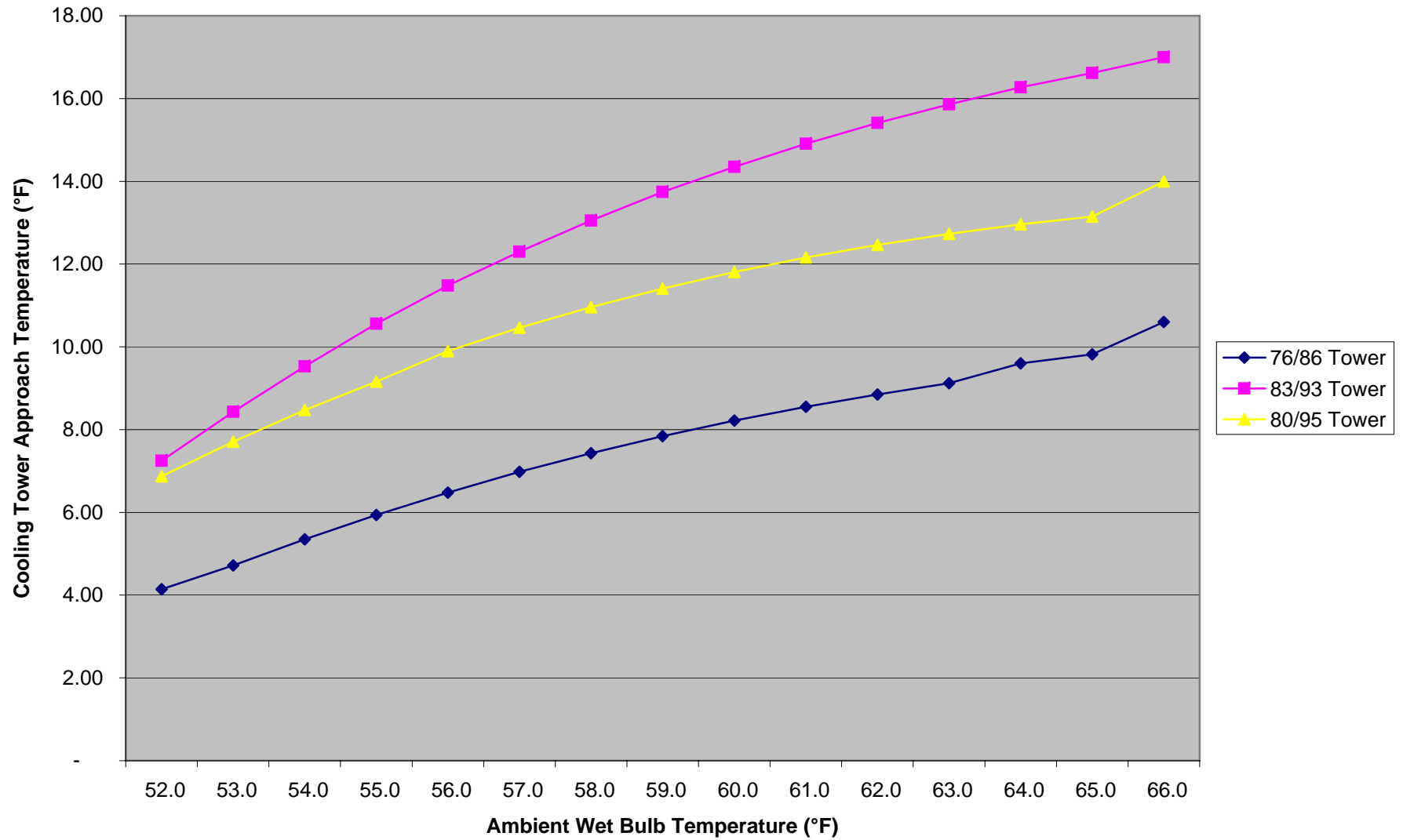
TABLE 112-H COPS FOR NON-STANDARD CENTRIFUGAL CHILLERS < 150 TONS

			Condenser Flow Rate					
			2 gpm/ton	2.5 gpm/ton	3 gpm/ton	4 gpm/ton	5 gpm/ton	6 gpm/ton
Leaving Chilled Water Temperature (°F)	Entering Condenser Water Temperature (°F)	LIFT[a] (°F)	Required COP					
46	75	29	5.58	5.83	6.03	6.32	6.54	6.70
45	75	30	5.50	5.74	5.92	6.19	6.38	6.53
44	75	31	5.42	5.65	5.82	6.07	6.24	6.37
43	75	32	5.35	5.57	5.72	5.95	6.11	6.23
42	75	33	5.27	5.49	5.64	5.85	6.00	6.11
41	75	34	5.19	5.41	5.56	5.75	5.89	5.99
46	80	34	5.19	5.41	5.56	5.75	5.89	5.99
40	75	35	5.11	5.33	5.48	5.67	5.79	5.88
45	80	35	5.11	5.33	5.48	5.67	5.79	5.88
44	80	36	5.03	5.26	5.40	5.58	5.70	5.79
43	80	37	4.94	5.18	5.32	5.50	5.62	5.70
42	80	38	4.84	5.10	5.25	5.43	5.53	5.61
41	80	39	4.73	5.01	5.17	5.35	5.46	5.53

Centrifugal Chillers < 150 Tons
COPstd = 5.0

Chiller Plant Energy Use
76/86 Tower Design

Cooling Tower Efficiency

Chilled Water Plant kW

A line chart titled "Chilled Water Plant kW" with x-axis labeled "Percent Load" ranging from 30% to 100% in 5% increments, and y-axis labeled "System Power Input (kW)" ranging from - to 400 in increments of 50. Three curves are plotted:
- 76 / 86 Tower (dark blue, diamond markers)
- 83 / 93 Tower (magenta, square markers)
- 80 / 95 Tower (yellow, triangle markers)